Produced Water Treatment – A Challenge

The Cause

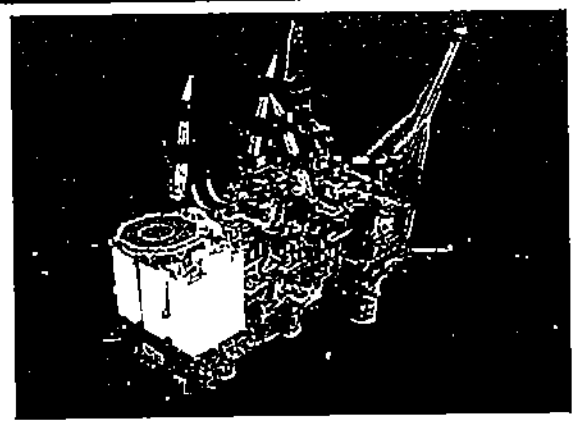
New compositions due to tie-in from new wells
Increasing water cuts
Presence of chemicals and suspended particles
Water salinity
Aging in the system

The Effect

Too small and stable oil droplets for efficient separation

The Future

Increasingly harder environmental legislation?



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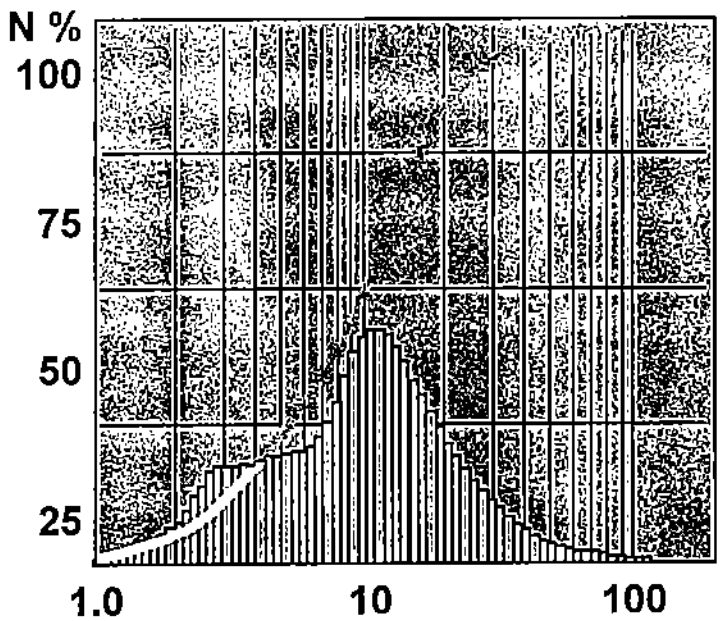
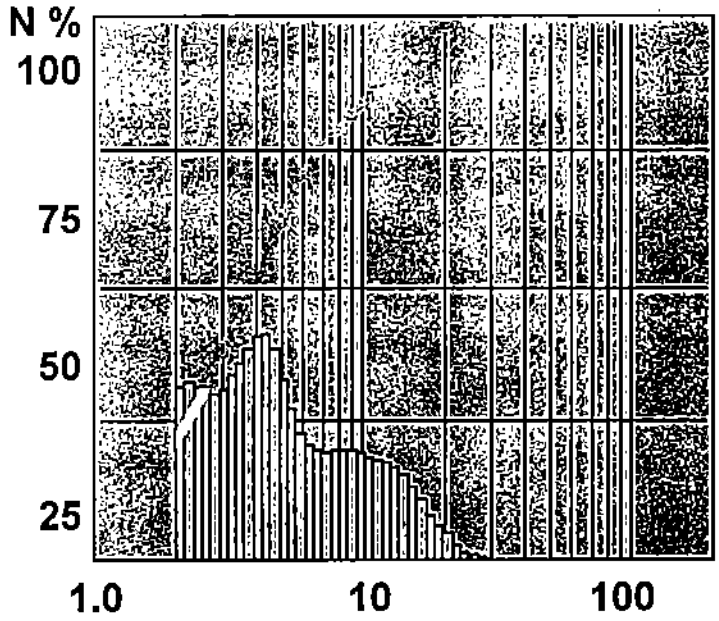
The Challenge: Small Oil Droplets

Typical droplet size distribution
in water from gas lift production



Typical droplet size distribution
in hydrocyclone reject



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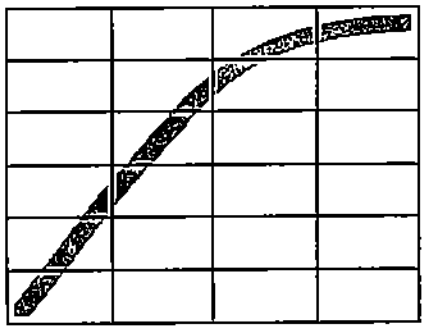
Droplet Size and Settling Velocity

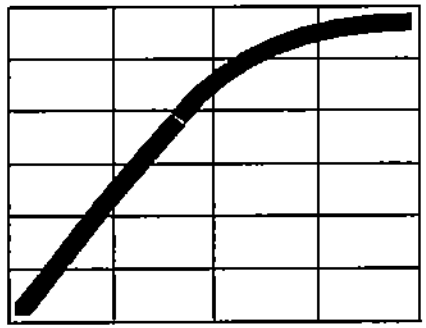
The Smaller the Droplets the Lower the Separation Efficiency

Separation efficiency



(*d*) Oil droplet size

Separation efficiency

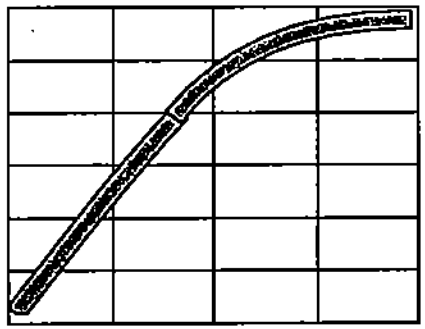


(ρw–ρo) Density difference

Stokes' Law

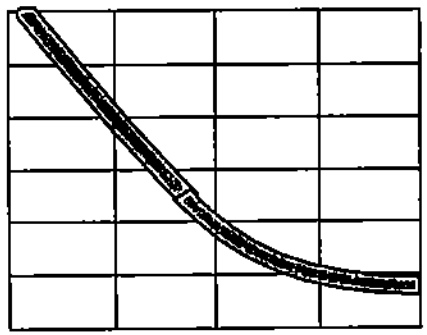
$$V_g = \frac{d^2(\rho_w - \rho_o)}{18\eta} g$$

Separation efficiency



(g) g-force

Separation efficiency



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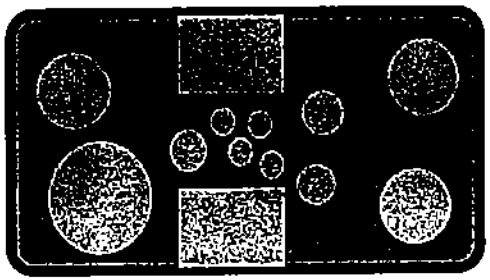
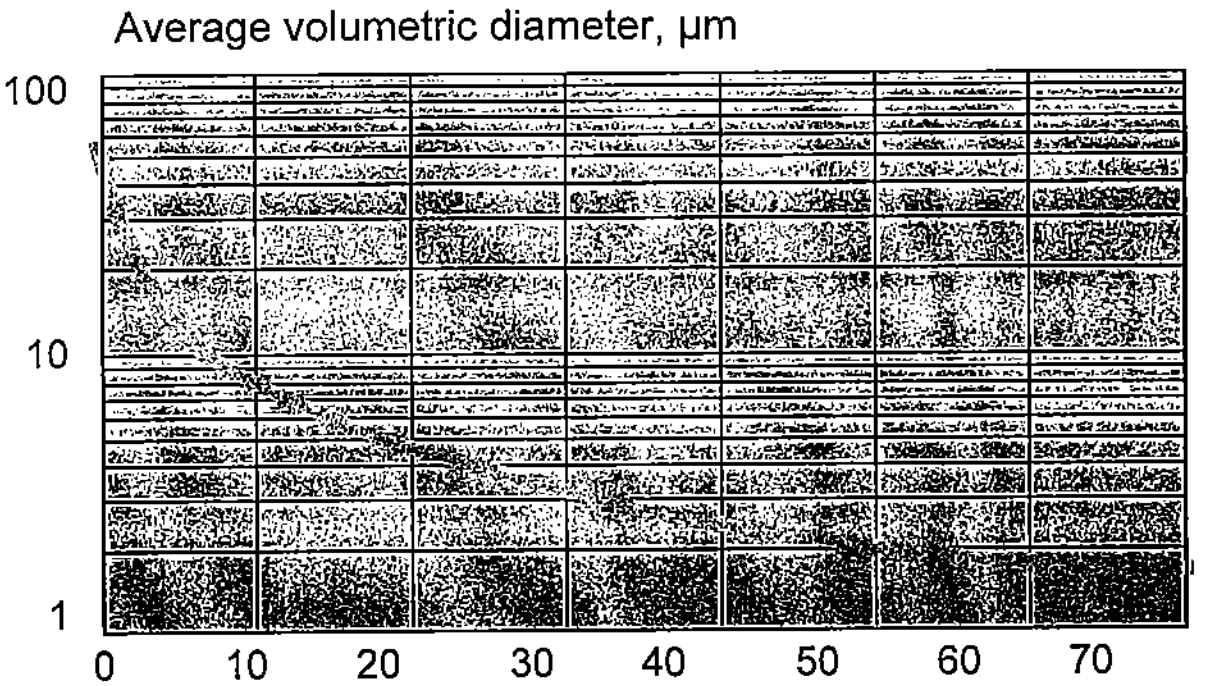
Mechanical Break-up of Droplets



Droplet generation by choke valve

Droplet size created as a function of pressure drop



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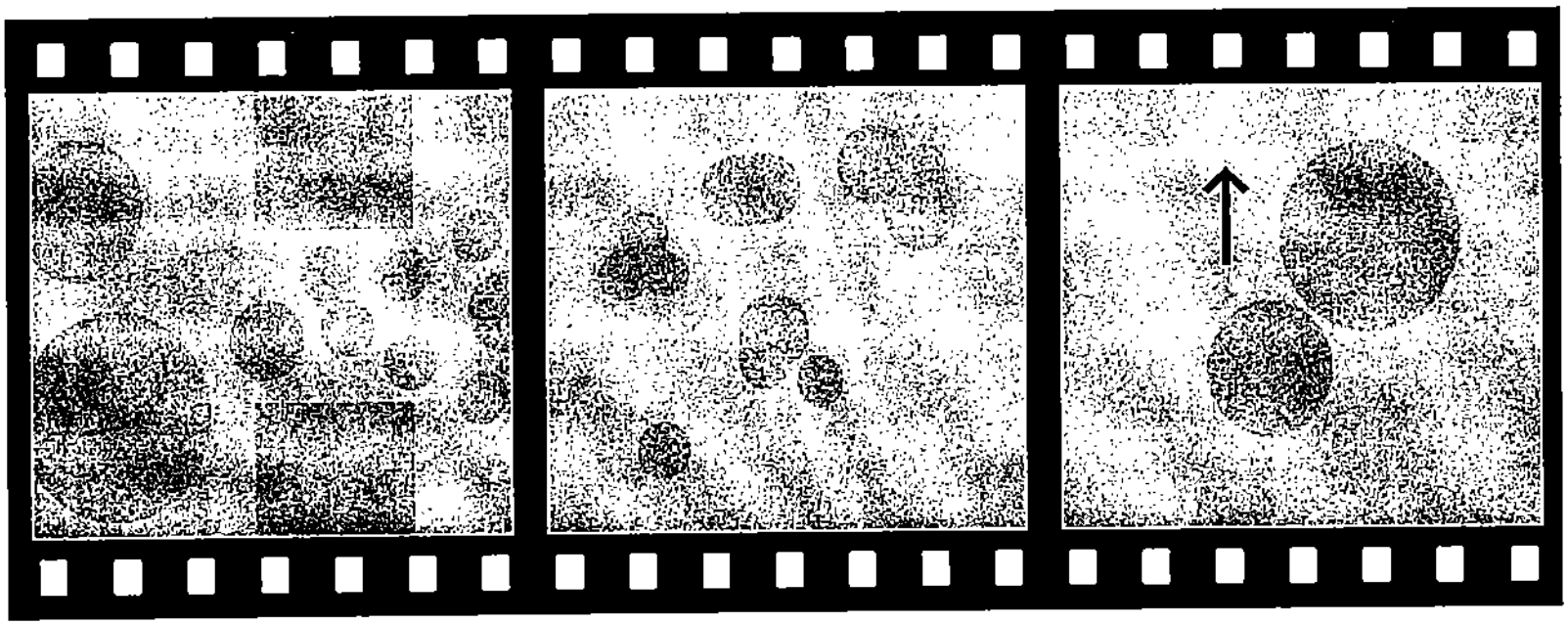
Coalescence

A Prerequisite for Separation

$$V_g = \frac{d^2(\rho_w - \rho_o)}{18\eta} g$$



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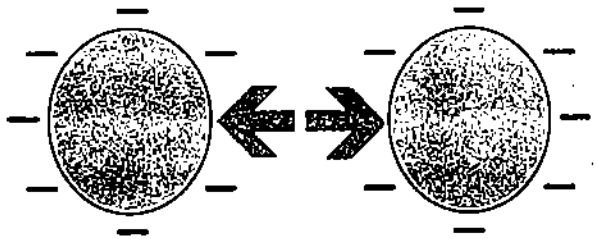
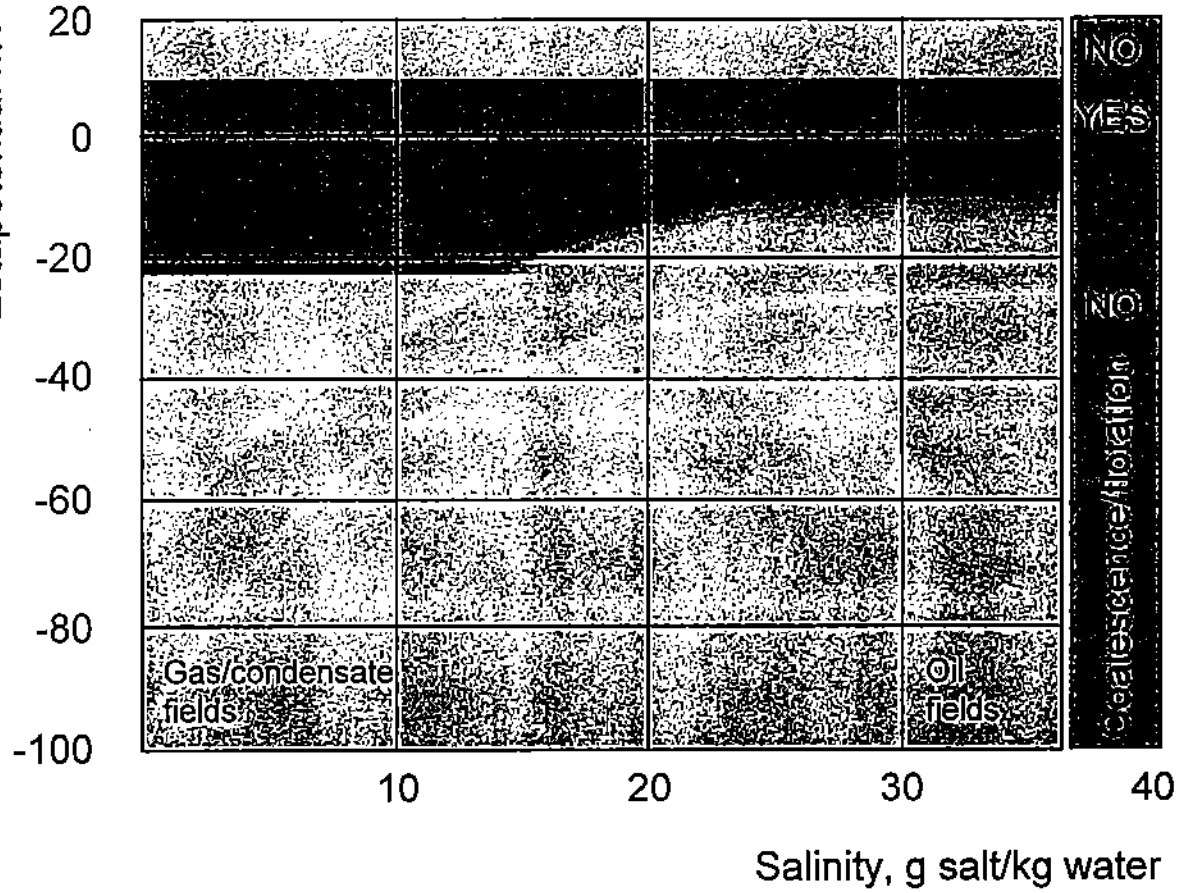
Water Salinity and Coalescence

The effect of water salinity (and electrostatic charge) on droplet coalescence

$$V_g = \frac{d^2(\rho_w - \rho_o)}{18\eta} g$$



The electrostatic charge causes the oil droplets to repel one another



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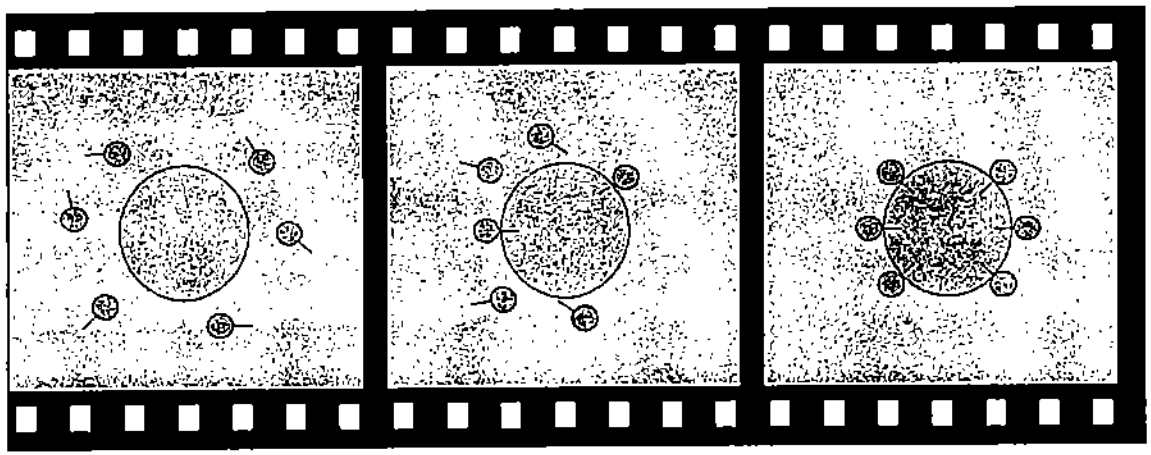
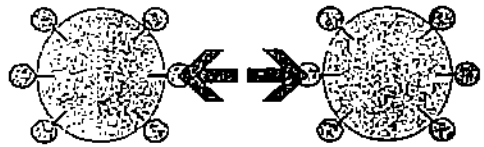
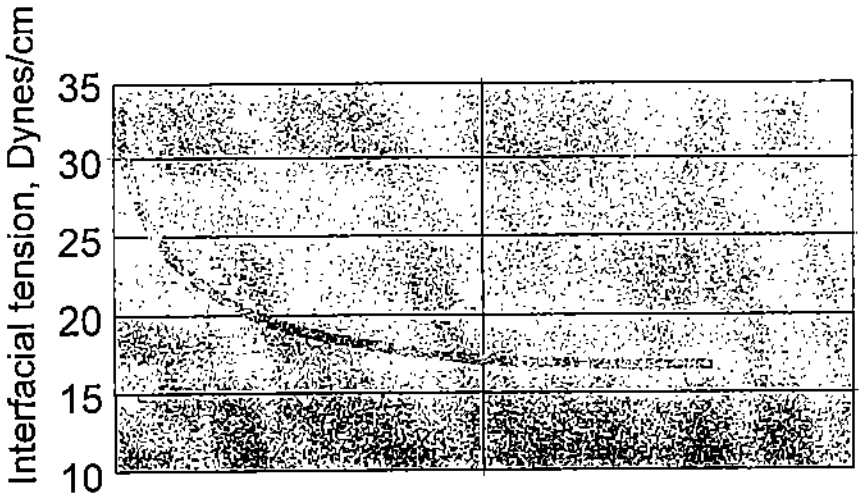
Ageing and Coalescence

Time



The effect of suspended particles and surface active chemicals





The effect of aging on droplet stabilization

$$D_{max} = C\left(\frac{\sigma^{0.6}}{\varepsilon^{0.4} \cdot \rho^{0.2}}\right)$$

Hinze's equation

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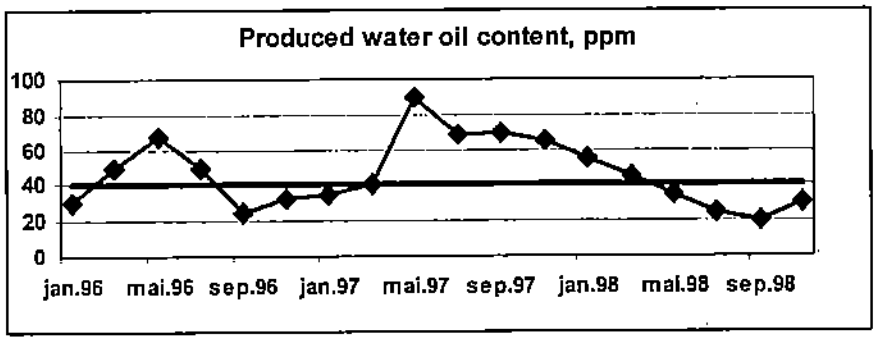
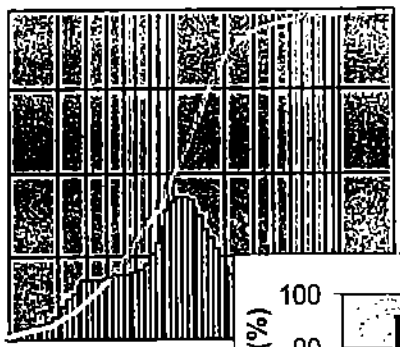
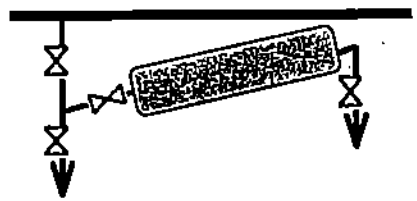
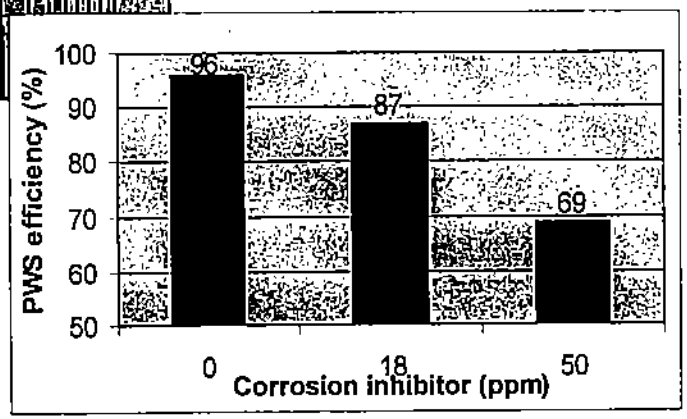
Mapping the Process

The Key to Solving the Separation Problem









- **Optimize separator operations w.r.t produced water quality**
- **Optimize hydrocyclone and degasser performance.**
- **Test and select the best performing produced water chemical, including adjustment of the dosage rate.**
- **Testing of alternative produced water equipment.**
- **Study the effects of recirculated streams on produced water quality.**
- **Testing and analysis of produced water w.r.t. reinjection.**

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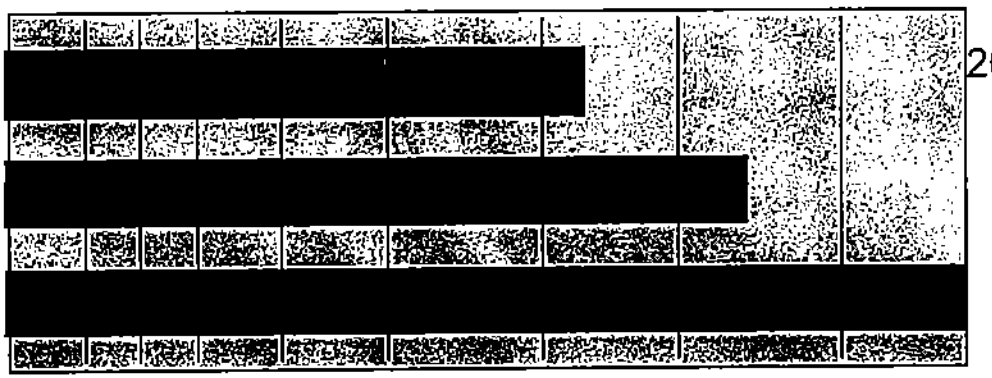
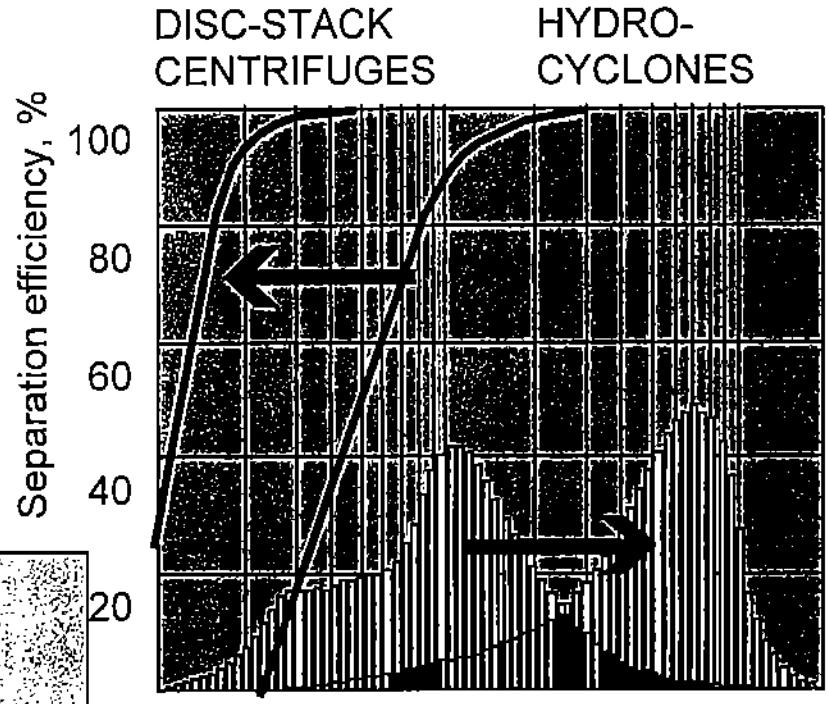
Separation Efficiency vs Droplet Size

$$V_c = \frac{d^2(\rho_w - \rho_o)}{18\eta} r\omega^2$$

Larger droplets
or higher g-force
– or both

Smallest oil droplets removed
by different separation systems





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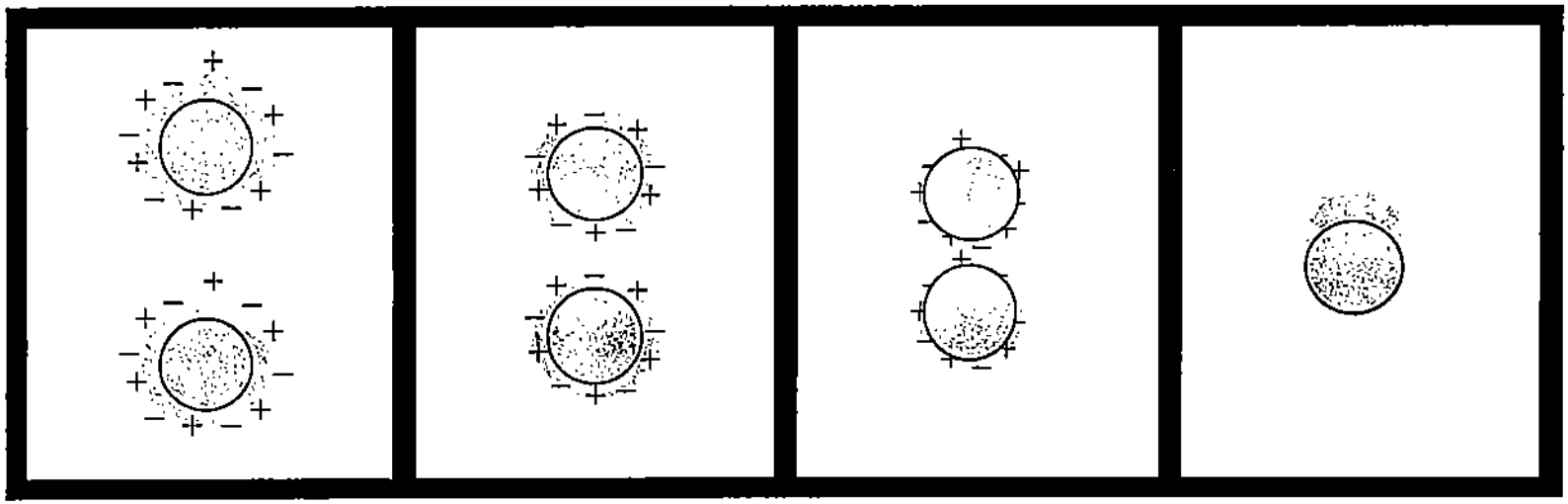
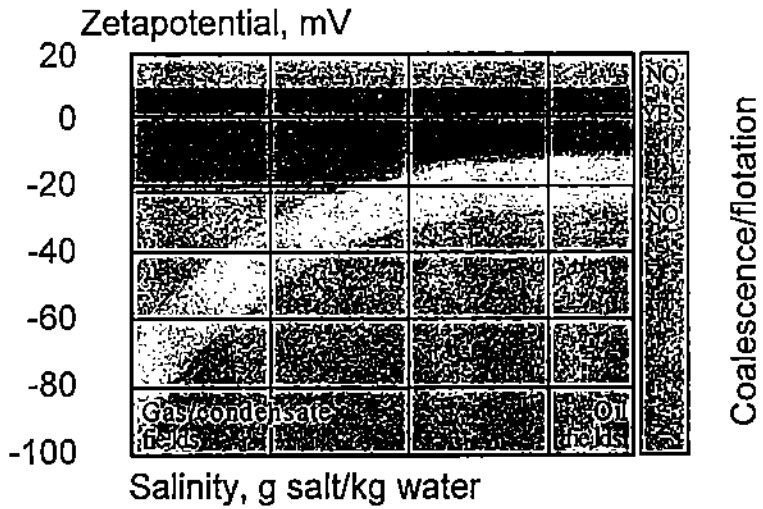
Coagulation
Stage One in the Hydroflokk System



Adding of coagulant



The effect of water salinity on droplet coalesecence

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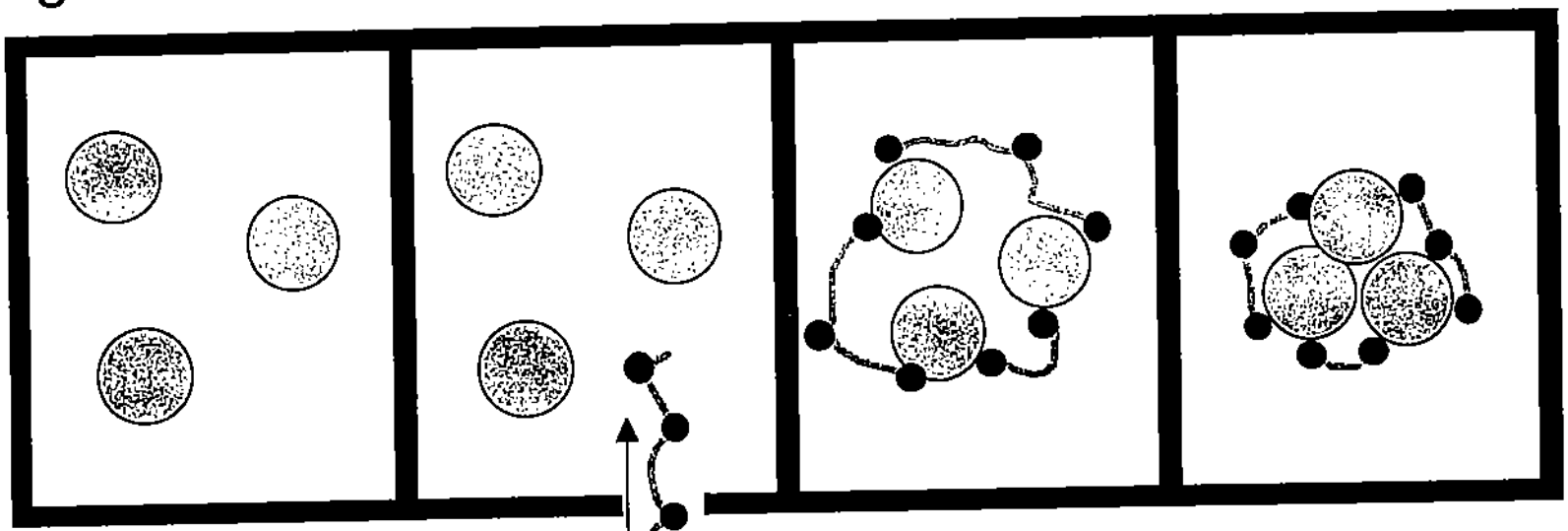
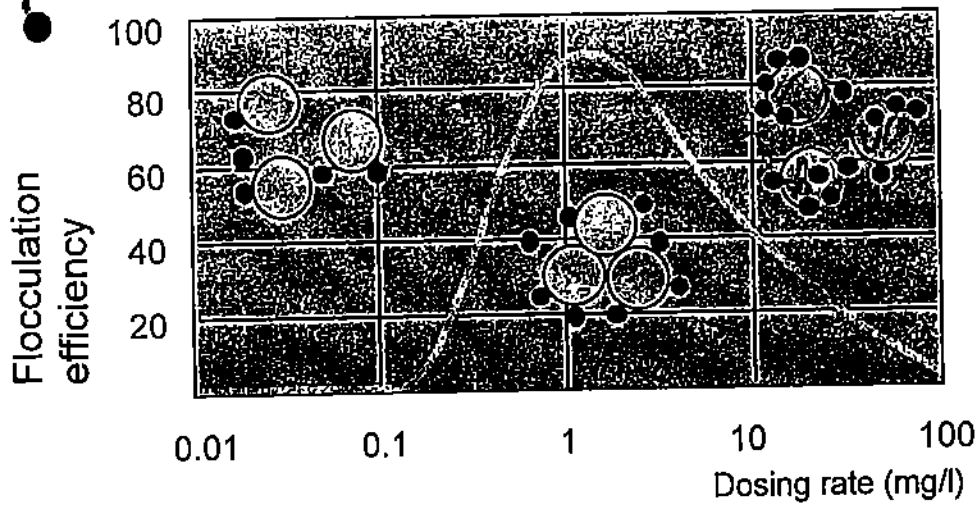
Flocculation

Stage Two in the Hydroflokk System



Polyelectrolyte

● Positive charged groups



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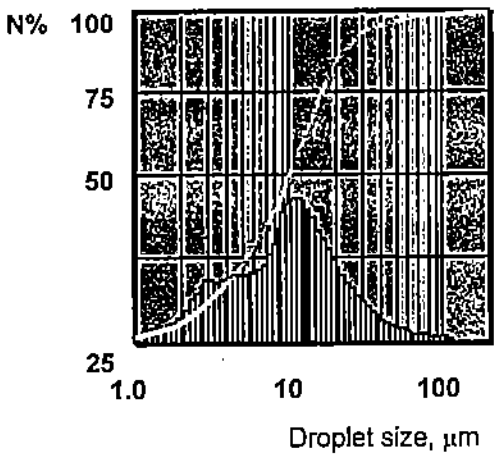
A Look at the Hydroflokk System

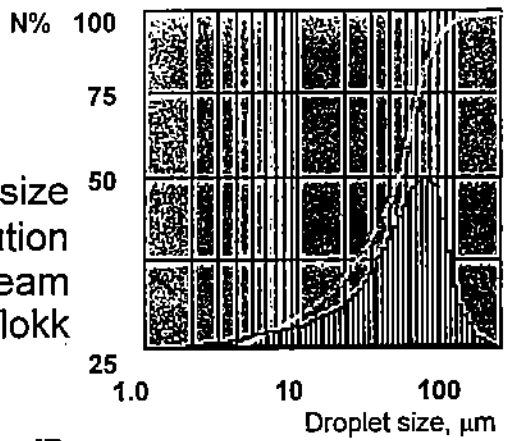
Coagulant

Produced water
from inlet separator



Droplet size distribution prior to Hydroflokk

Flocculant



Droplet size distribution downstream Hydroflokk

Produced water
to treatment system

Benefits of Hydroflokk:
Less oil in discharged water
Reduced use of chemicals

Controlled oil droplet growth by optimized
– composition of chemicals
– concentration of chemicals
– agitation
– retention time

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Benefits of Hydroflokk

- Consistent and acceptable discharge water quality
- Improved performance from deoiling hydrocyclones
- Optimised chemical performance
- Substantially reduced operating costs
- Greater flexibility of the separation process
- Potential to realise improved oil quality
- Potential for debottle-necking existing systems

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Troll B challenges

- **Large volumes !!**

  Q = 40 000 Sm3/d = 252 000 blpd

- **High concentration !!**

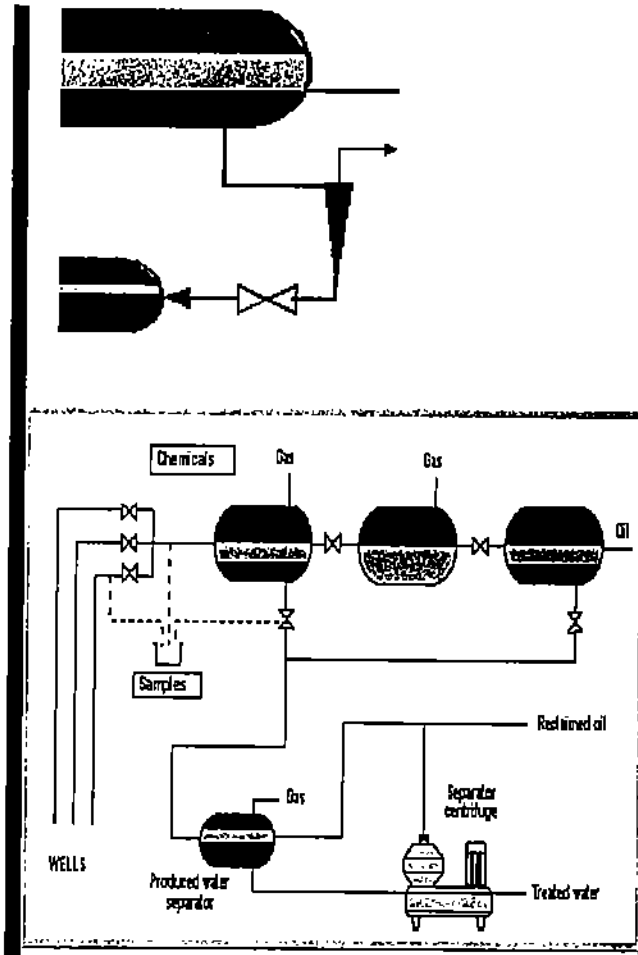
  OiW = 500 - 1 500 ppm

- **Small oil droplets !!**

  dv50 = 5 µm

- **Low target value for disposal !!**

  Discharge OiW target = 25 ppm



How to handle this ??

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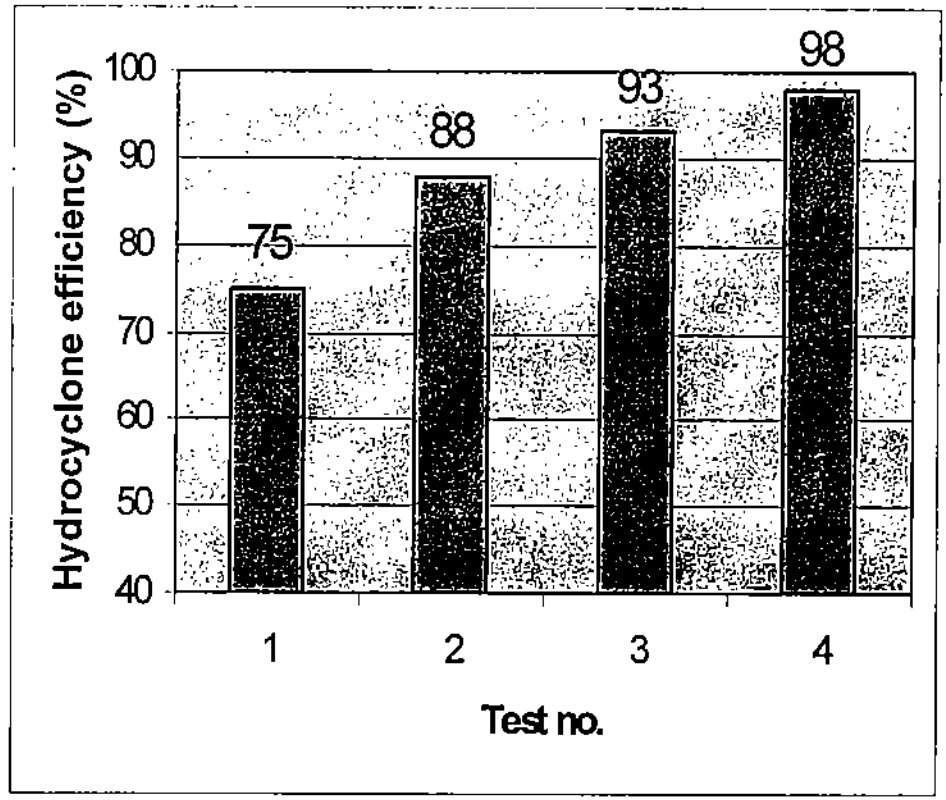
Pilot plant test results

Conditions: P=12barg, T=50°C, OiW=1000ppm, d_{v50}=5µm, reject=2-3%

Test no. :

1. **Hydroflokk not included.**
2. **Flocculation vessel included, no chemicals.**
3. **One component system.**
4. **Two component system.**



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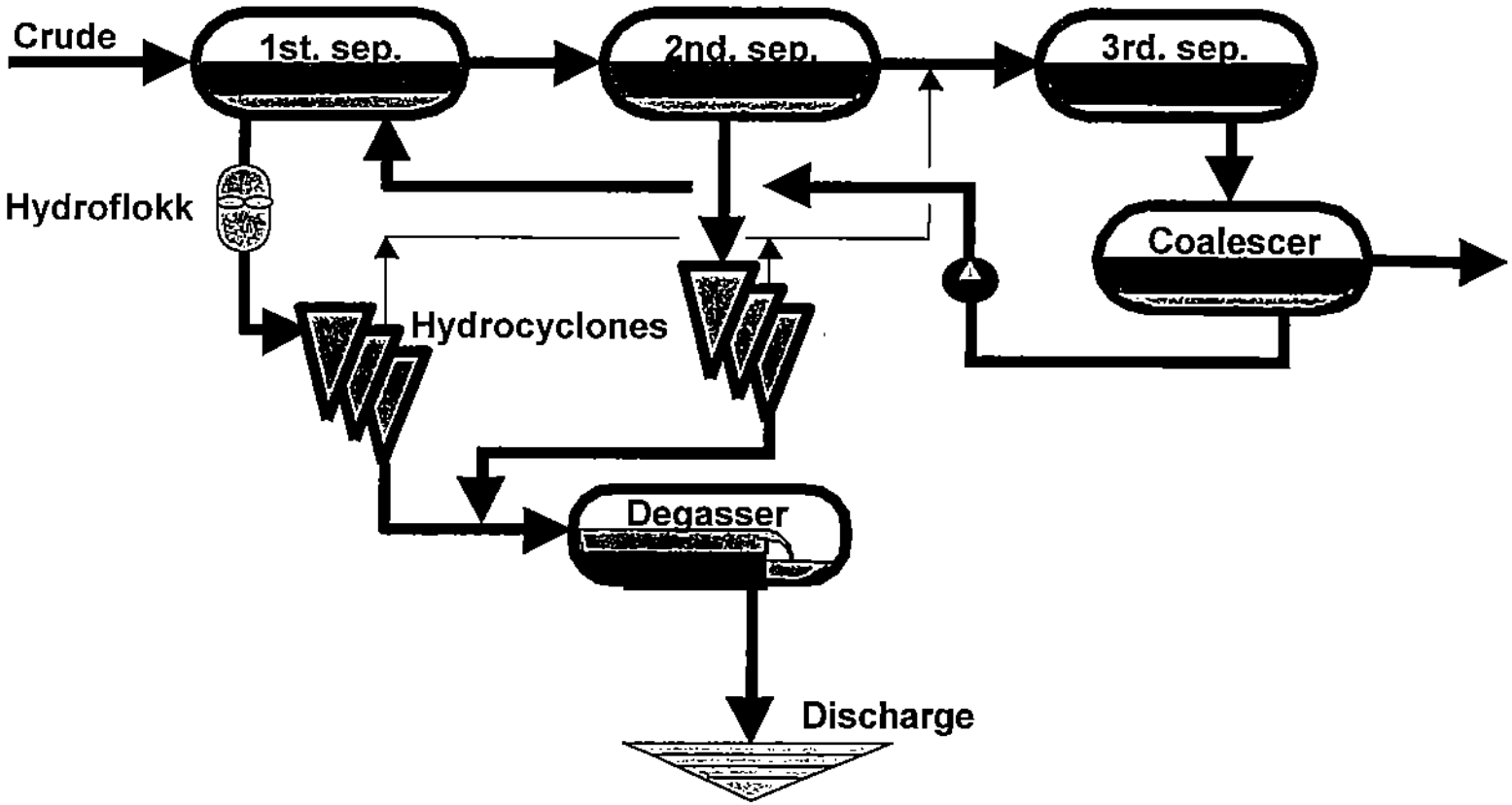
Troll B flow diagram



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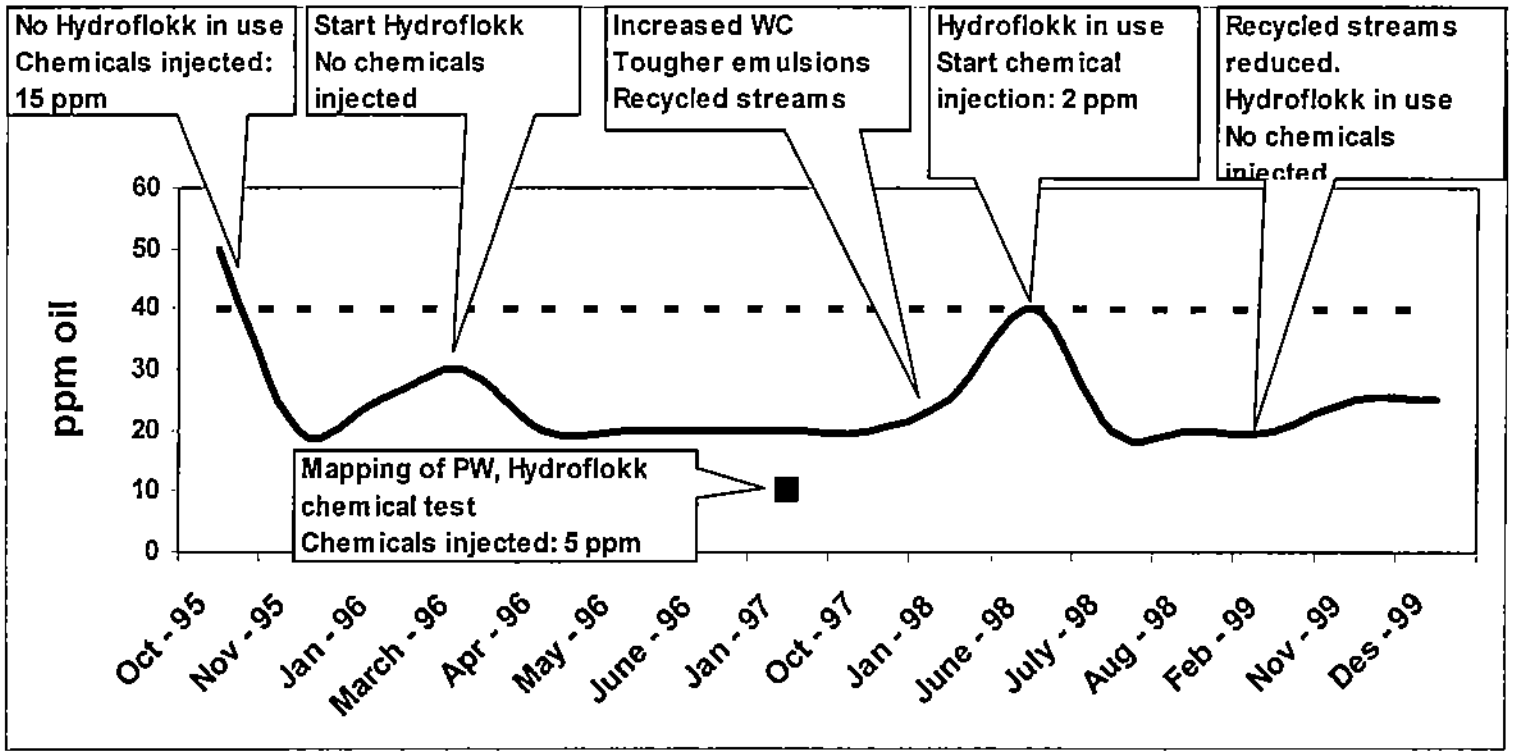
Troll B History

Troll B - oil in water discharge



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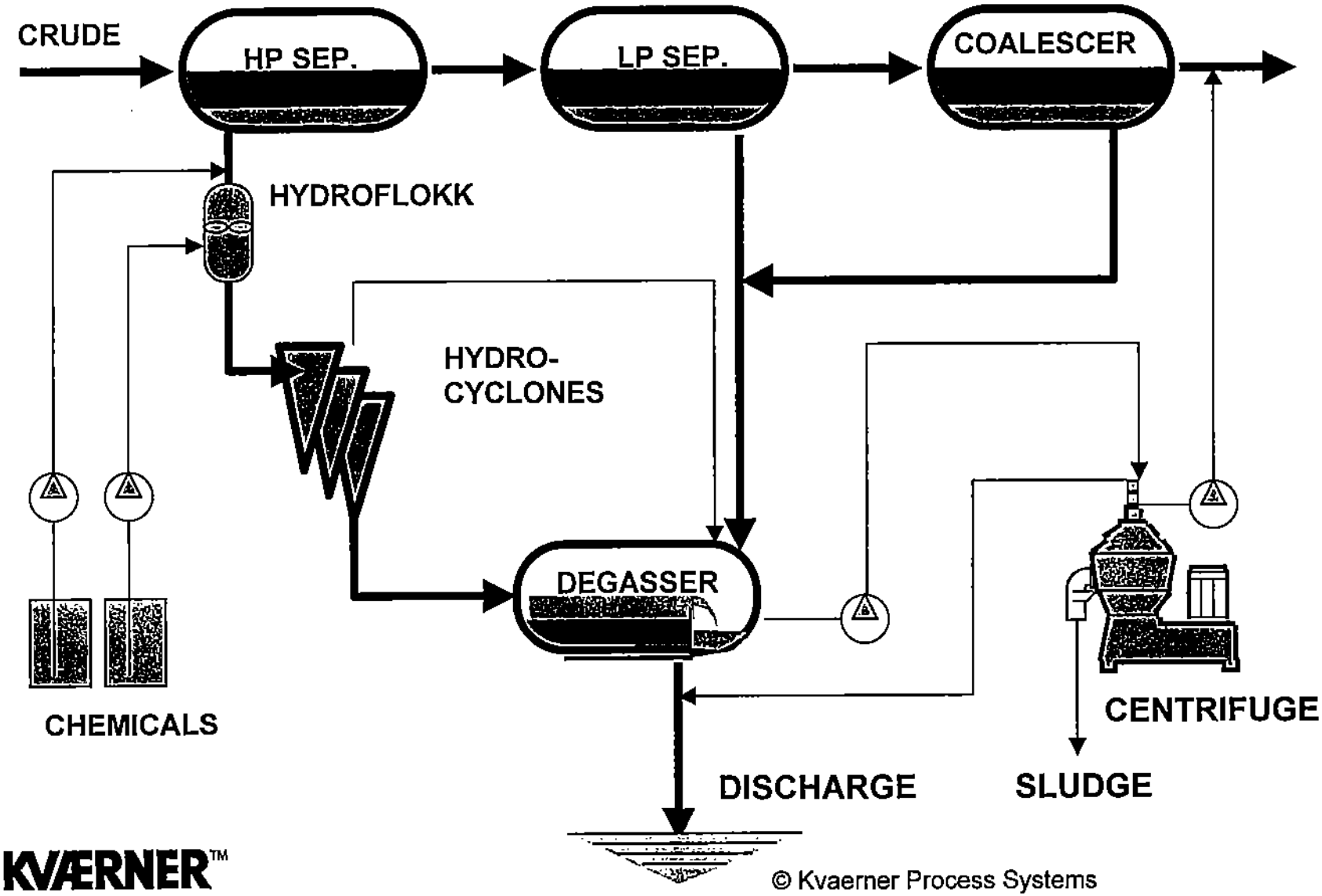
Troll C flow diagram



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